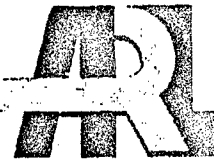ARMY RESEARCH LABORATORY

A Proposal for an Active/Passive Signature Enhancer for Identification Friend-or-Foe

by Marcos C. Sola, E. Glenn Dockery, Joseph A. Penn, Paul L. Zirkle
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Army Research Laboratory

Adelphi, MD 20783-1197

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Sensors and Electron Devices Directorate

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Abstract

A major factor in the U.S. casualties during Operation Desert Storm was friendly fire. To minimize fratricide, signature tags on Blue (friendly) Force weapon platforms were used to enhance the level of acquisition of night-vision devices. These signature enhancements, however, could also be an excellent cue to the enemy and could result in increased Blue Force casualties. This report discusses the use of optical augmentation (OA) in conjunction with an active/passive signature enhancer (APSE) for identification friend-or-foe (IFF).

For military use, the APSE, interrogated with OA sensors on a platform such as a reconnaissance helicopter, will allow positive IFF between opposing forces at tactical range. In addition, due to the directional nature of the APSE reflection, the Red (enemy) Force, would not be able to intercept the reflected laser energy from the APSE unless the enemy is directly close along the optical path of the laser beam.

The APSE used with night-vision sensors could also have nonmilitary applications such as helping law enforcement officials with nighttime raids and assisting search-and-rescue personnel in missions to help vessels in distress. Whether for a military or nonmilitary application, the use of the APSE in conjunction with the appropriate devices will enhance positive identification and will allow for shorter detection times, which translates into saving lives and property.

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1. Background

Retroreflection, also referred to as optical augmentation (OA), is a technique used for detecting electro-optical (EO) sensors. In a military application, this is done by using an imaging system with a co-located, co-boresighted, in-band laser source. The signal reflected from the targeted sensor is the means for detection. An example of this type of detection is the reflection from an animal's eyes of an automobile's headlights at night. This detection technique has military and nonmilitary uses, such as for battlefield identification friend-or-foe (IFF) or for a search-and-rescue mission of vessels in distress in a littoral environment. This report discusses the results of two field demonstrations and a computer-simulated study and the use of this detection technique in conjunction with an active/passive signature enhancer (APSE) for dual-use technology.*

2. Sensors

For OA to occur, the in-band laser is co-located and co-boresighted with an imaging sensor, and there must be at least a partial alignment between the search sensor and the targeted sensor. The size of the return signal due to OA is a function of the optical cross section of the targeted sensor, the alignment between the targeted and search sensor, the laser power, the range to target, and the intervening atmosphere (which may be natural, artificially generated, or both).

The two prototype sensor systems that we used were designed and put together by the Army's Night Vision and Electro-Optics Laboratory.† The systems are called Foxfire 1 and Foxfire 2. Foxfire 1 is a first-generation forward-looking infrared (FLIR) sensor coupled with a carbon dioxide (CO_2) laser, and Foxfire 2 is an image intensifier coupled with a gallium aluminum arsenide (GaAlAs) laser. (See fig. 1 and table 1.) All the parts of the systems are commercially available to authorized purchasers.

3. Hunter-Liggett Demonstration

In the summer of 1985, the Survivability Management Office of the Laboratory Command (LABCOM), now the Army Research Laboratory, led a piggyback experiment with the support of the Night Vision and Electro-Optics Laboratory in a field test called Thermal Pin Point.‡ Simultaneous imageries were recorded with both Foxfire systems. Several targets were
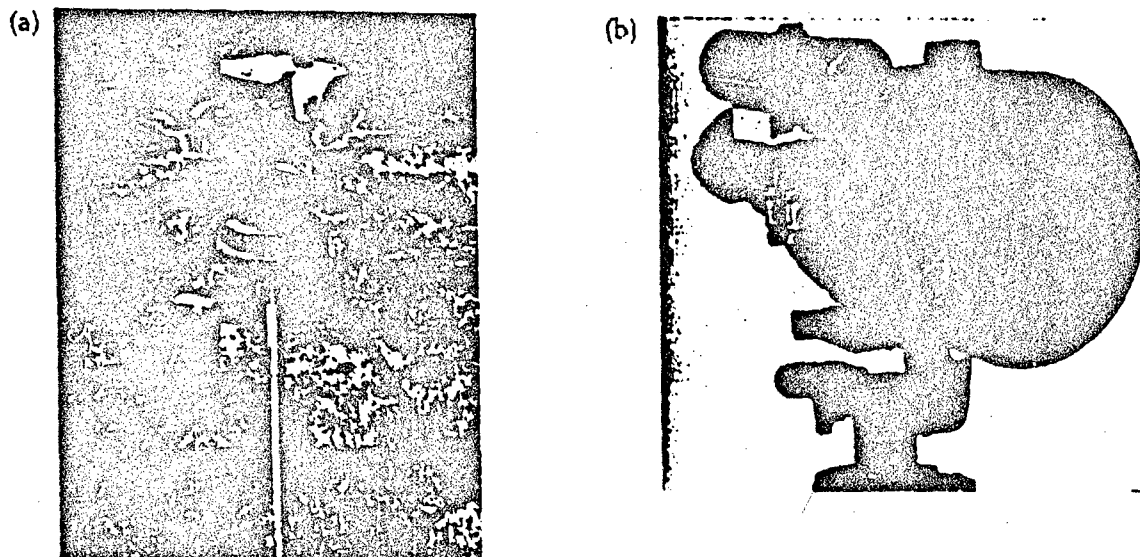
Figure 1. (a) Foxfire 1 system: AN/TVS-6, Night Observation Device, Long-Range (NODLR) with CO_2 laser and (b) Foxfire 2: AN/TVS-5, Crew Serve Weapon System (CSWS) with GaAlAs laser.

Table 1. Attributes of Foxfire 1 and Foxfire 2.

Foxfire 1

AN/TVS-6 (NODLR)	CO_2 laser
Spectral band = 8–12 µm	Wavelength = 10.6 µm
NFOV = 1.1° × 2.3°	Beam divergence = 20 mr
WFOV/NFOV = 3	Peak power = 20 W
Magnification = 9	(Average measured power = 1 W)
	Pulsed: No
	Duty cycle: n/a
	Pulse width: n/a

Foxfire 2

AN/TVS-5 (CSWS)	GaAlAs laser
Spectral band = 0.4–0.9 µm	Wavelength = 0.83 µm
NFOV = 9°	Beam divergence = 20 mr (variable)
WFOV/NFOV = 1	Peak power = 100 mW
Magnification = 6	(Average measured power = 20 mW)
	Pulsed: 6 Hz
	Duty cycle: 30%
	Pulse width: 50 ms

NFOV = narrow field of view; WFOV = wide field of view.

placed 4.3 km from the search sensors. The targets were a 2-in. corner cube; a 4-in. corner cube; a Foxfire 2 system; and a dismounted tube-launched, optically tracked, wire-guided (TOW) missile system without the tube launcher (see fig. 2).

This demonstration was conducted at night with visibility greater than 6 km. This was a field demonstration of a concept and not a field

Figure 2. Dismounted
TOW missile system
without tube
launcher.

experiment. Imposing the Signature Quality Metrics [1] requirement was not adhered to in order to save money and personnel resources. Figure 3 is an image of tne hill where the targets were located as seen by the Foxfire 2 system in the passive mode.

The user of each sensor system was asked to search a field of regard (FOR) of approximately 90°. At this range, the targets that were used were well beyond the resolution capability of either system. When the systems' lasers were activated, however, they created a footprint of approximately 9 m in diameter, and the targets were located in a matter of seconds. Figure 4 shows retroreflection from all four targets. The second target from the left is a Foxfire 2 system that is active and has a partial co-alignment with the search sensor. A drawback of this technique is the detection of the laser beam by an enemy's passive in-band sensor; survivability of the passive sensor can be increased by the use of reflecting surfaces as decoys to increase false alarm rate. Therefore, the use of our detection technique would be better suited for an attacking force (e.g., a small flotilla raiding a coastal area, drug agents in a convoy attacking a drug laboratory, or a mechanized unit assaulting a hill) where the main concern of the attacking force is ambush because its location is already known by the enemy, either due to its size or to strategic placement of surveillance sensors. In this demonstration, there was sufficient return signal from both prototype sensors such that the source-to-target sensor separation distance could have been increased. However, the physical terrain did not permit us to extend our line of sight (LOS) requirement.

Figure 5 is a view seen by the passive targeted sensor when it is identified by the search sensor (Foxfire 2). Even with the low-level laser power associated with this system, the search sensor was able to dazzle the targeted sensor to where it could not produce any useful image for acquisition. (The grids are the fixed-pattern noise of the microchannel plate.)

Figure 3. Passive-mode Foxfire 2 system (image intensifier) image of a hill at 4.3 km distance with targets (Hunter-Ligget demonstration).
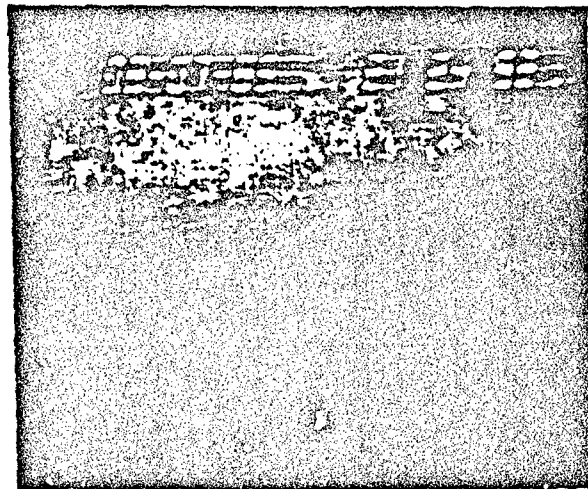

Figure 4. Retroreflection from target seen by Foxfire 2 sensor. Four targets are located on a hill at 4.3 km distance (Hunter-Liggett demonstration).
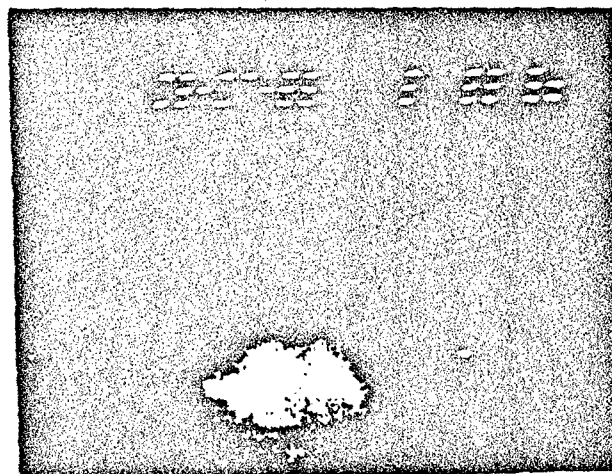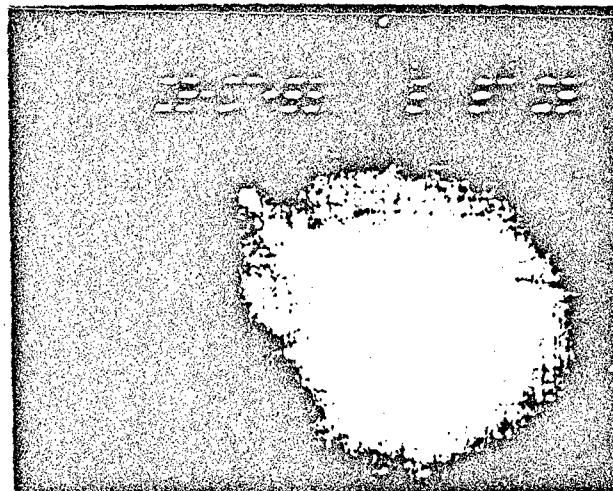

Figure 5. View of image intensifier located by Foxfire 2 system. Note that targeted sensor is "dazzled"; thus no useful target acquisition could be made (Hunter-Liggett demonstration).

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4. Demonstration for the U.S. Coast Guard

As part of the dual-use-technology approach, we demonstrated that this detection technique could be used in conjunction with an APSE to perform a search-and-rescue (SAR) mission in a littoral environment. We thought that this combination of techniques would prove to be beneficial because it would provide positive identification, reduce the time needed to find a vessel in distress in a crowded or target-rich environment, and minimize the on-the-scene time that SAR personnel would need for their work at a possibly dangerous site. Achieving these results should not only save lives and property, but also save taxpayers' dollars. The nighttime demonstration was done on 11 July 1995, at Gunston Cove, FT Belvoir, VA.* Figures 6 (a) and 6 (b) are views through the FLIR sensor and were taken from atop the Night Vision and Electronic Sensors Directorate building—the location of the search sensors. Figures 6 (a) and 6 (b) are views through an infrared imaging system with (6 (a)) and without (6 (b)) the active source (CO_2) overlooking Gunston Cove, FT Belvoir, VA. This view shows part of the FOR in the search for two vessels that were supplied by Flottila 29, Division II, 5th District, U.S. Coast Guard Auxiliary. Both vessels were certified as operational facilities by the U.S. Coast Guard. They were both 24-ft cabin cruisers with single inboard/outboard engines. The lead vessel— auxiliary vessel 24833—had an APSE mounted on its stern. The visibility for the APSE was $\pm135°$ from dead stern. Following the lead vessel was auxiliary vessel 24498. It had reflector tape on the port and starboard sides of its cabin.

One vessel was used as a baseline and the other was "jury-rigged" with an APSE. Simultaneous recordings of the targets were done with Foxfire 1 and 2 systems mounted on a common tripod. This insured that whatever scenario one system was looking at, the other system would see almost the same view (allowing for differences in each system's field of view). For this demonstration, the range was limited, and the targets were never beyond the resolution and sensitivity range of the imaging sensors. Maximum range obtained for this demonstration was about 1 nautical mile, due again to the need for LOS and the constraint imposed by the treelines on the shore in some parts of the FOR search.

In order to ensure a positive, distinct signal return from the APSE, a higher-fidelity diagram is proposed as shown in figure 7 [2]. Two concentric spheres of radius R_1 and R_2 are shown with the corner cubes (C) of a given aperture A_c placed along the inner sphere, with the corner cube separation of S_c. For each corner cube, a baffle of length B_d is created. The baffle length equals the distance between R_2 and R_1. This signal allows for a unique or coded return when placed along a chosen lateral plane of the sphere perpendicular to its rotation. The sphere in this figure is rotating with an angular velocity ω coming normal from the paper. There is a

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*Demonstration by M. Sola and E. G. Dockery, ARL, and Flotilla 29, Division II, 5th District, U.S. Coast Guard Auxiliary for U.S. Coast Guard, Research and Development Center Chief Scientist (Q. Robe), FT Belvoir, VA (11 July 1995).

Figure 6. Views through infrared imaging system (a) with and (b) without the active source (CO_2).
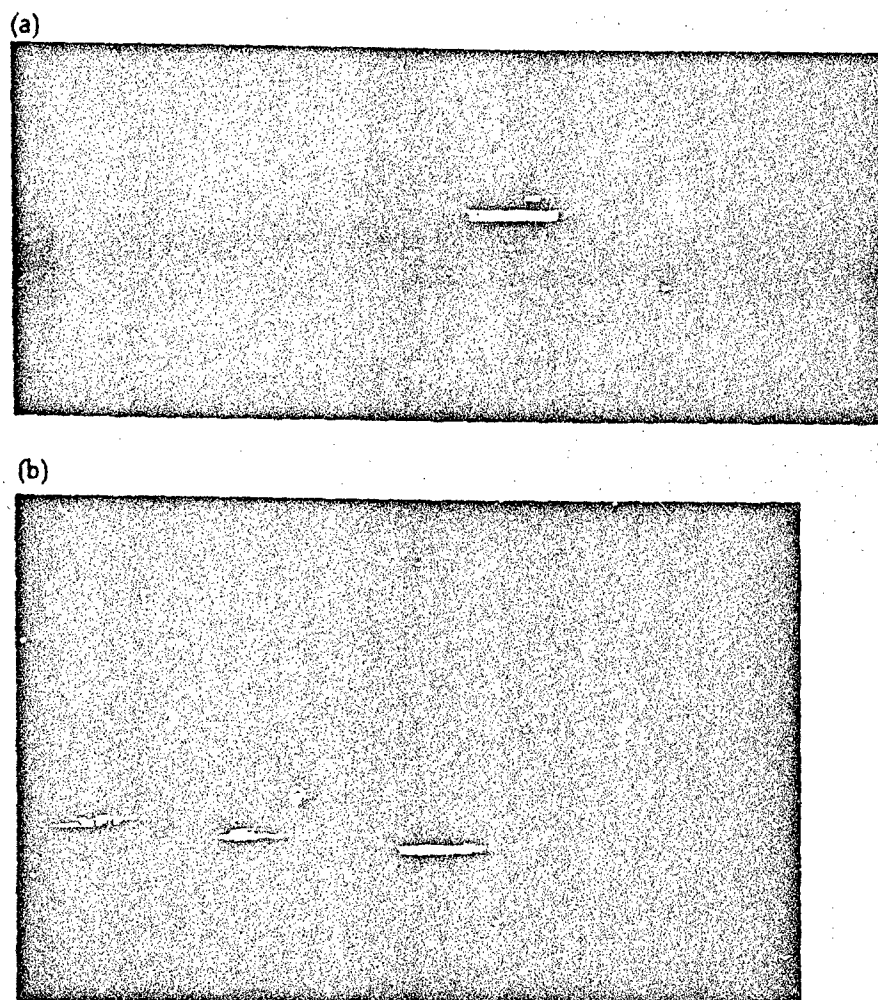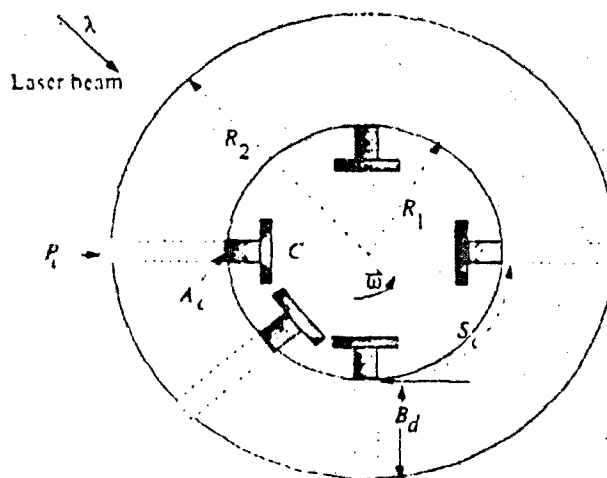
(a)

(b)

Figure 7. Configuration of higher fidelity active/passive signature enhancer.

protective cover P_c with a wide dynamic transparent range to the incident laser energy wavelength (λ_i) that is coming from the source weapon platform. This cover protects the corner cubes from any debris that would damage their reflective property.

The number of positive, distinct codes that can be created for a fixed angular frequency is optimized by the selection of the size and number of the corner cubes, the corner cube separation distance along the lateral plane (normal to vertical rotation) of the inner sphere, and the baffle length.

Additional codes could be added to the above for integral number ($n \times \omega$) of the angular frequency, where $n = 1, 2, 3, \ldots$.

For nonmilitary applications such as SAR in a target-rich littoral environment, rotation of the sphere in the horizontal axis may provide an ac signal, provided there is enough contrast in the vertical (for example, sky versus water) in terms of light level or temperature difference, depending on the passive sensor (without the illuminator) that is in use. If the sphere is not rotating, the wave action could provide for a twinkling effect when viewed by sensors with illuminators, which is a good cue to the observer even if the ac signal-to-noise ratio is low against a predominantly dc background.

Removal of personnel from a vessel in distress in the dark and in heavy seas poses a danger for the SAR personnel. With the APSE, a Coast Guard helicopter pilot could receive coded signals. These signals could provide the pilot with a very good idea of the condition of the sea and its roughness.

The APSE mounted on Drug Enforcement Agency (DEA) vehicles could track the DEA vehicles and distinguish them from drug traffickers' vehicles in the case of multiple engagements. Mounted on small boats, the APSE would allow the law enforcement vessels that were performing interdiction of illegal aliens in the U.S. littoral environment to be tracked and vectored to proper targets.

5. Military Use

A major factor in the U.S. military casualties during Operation Desert Storm was friendly fire. To minimize fratricide, signature tags on Blue (friendly) weapon platforms were used to enhance the level of acquisition of night-vision devices (FLIRs or image intensifiers). These signature tags included rotating hot plates, thermal tapes, and/or luminescent strips for IFF that were placed on weapon platforms. These signature enhancements, however, could also be an excellent cue to the enemy if it had comparable night-vision devices. If the enemy also had the capability of attacking any target that it acquired, this could result in increased friendly force casualties. The use of the APSE and OA sensors would mitigate fratricide and inadvertent detection by the enemy.

To demonstrate the feasibility of this concept, we used a high-resolution synthetic scene generator model (SSGM) called CREATION [3], in lieu of the more expensive Advanced Concept Field Demonstration. Some of the attributes of CREATION for concept demonstration are portrayal of the type of sensor planned for use, multispectral target signature, terrain/background, and atmospheric environment, including smoke/obscurant. A generic approach to validation of any SSGM and in particular of the CREATION model is in progress [4]. Figure 8 (a) shows a simulated display onboard a Scout (reconnaissance) helicopter at stand-off range where it is safe from a tank gun or antitank missile. Although the targets are recognizable and within the tactical range of an attack helicopter's weapons, the problem is that the helicopter's pilot needs to distinguish friend from foe. As shown in figure 8 (b), the friendly forces are immediately identified when the laser is turned on. (The Scout helicopter can then pass this information to an Apache (attack) helicopter, which attacks the target.) Thus, the APSE allows for positive identification of friendly forces and platforms at distances that are greater than the detection range of a passive sensor.

The amount and type of smoke/obscurant that would defeat an onboard FLIR or image intensifier can be simulated by the CREATION model. Calculations were actually performed for various EO near- and far-infrared sensors and laser guidance systems as a function of weather, season, environment, geography, and types of smoke [5].

Figure 8. Simulated display on board a Scout helicopter: (a) ground targets are recognized as tanks, but are not identified as friend or foe and (b) Scout helicopter activates Foxfire 1 system and identifies two tanks (upper right-hand corner) as friendly forces.

(a)

(b)

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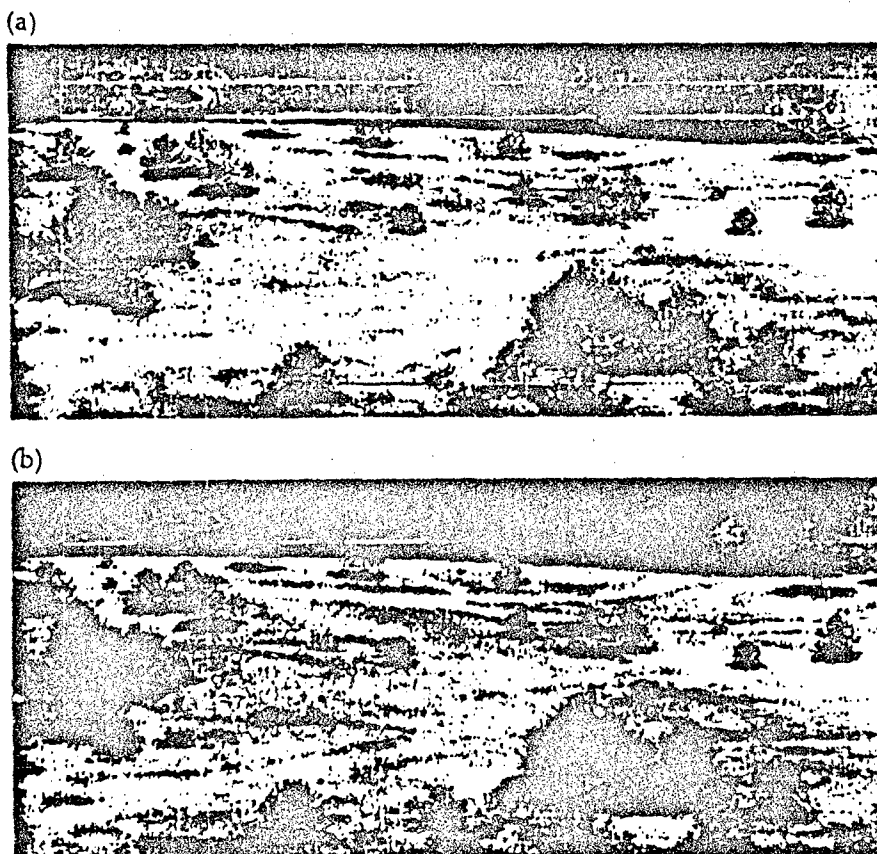
6. Recommendations

One conclusion from the CISC-97 Conference is that there is no "silver bullet" that would completely solve the fratricide problem. The signature enhancer along with the OA sensors discussed in this report can be used in conjunction with other IFF devices to mitigate fratricide. The ARL high-resolution synthetic scene rendering model CREATION, can be used to simulate and analyze future IFF concepts before actual field demonstrations, thus saving dollars and resources.

Acknowledgments

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13. ABSTRACT (Maximum 200 words)

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13. Abstract (cont'd)

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